
AIR VEHICLES TECHNOLOGY:
BETTER PERFORMANCE, REDUCED VULNERABILITY
AIR FORCE MATERIEL COMMAND
Col Gerry Hasen
Acting FI Director

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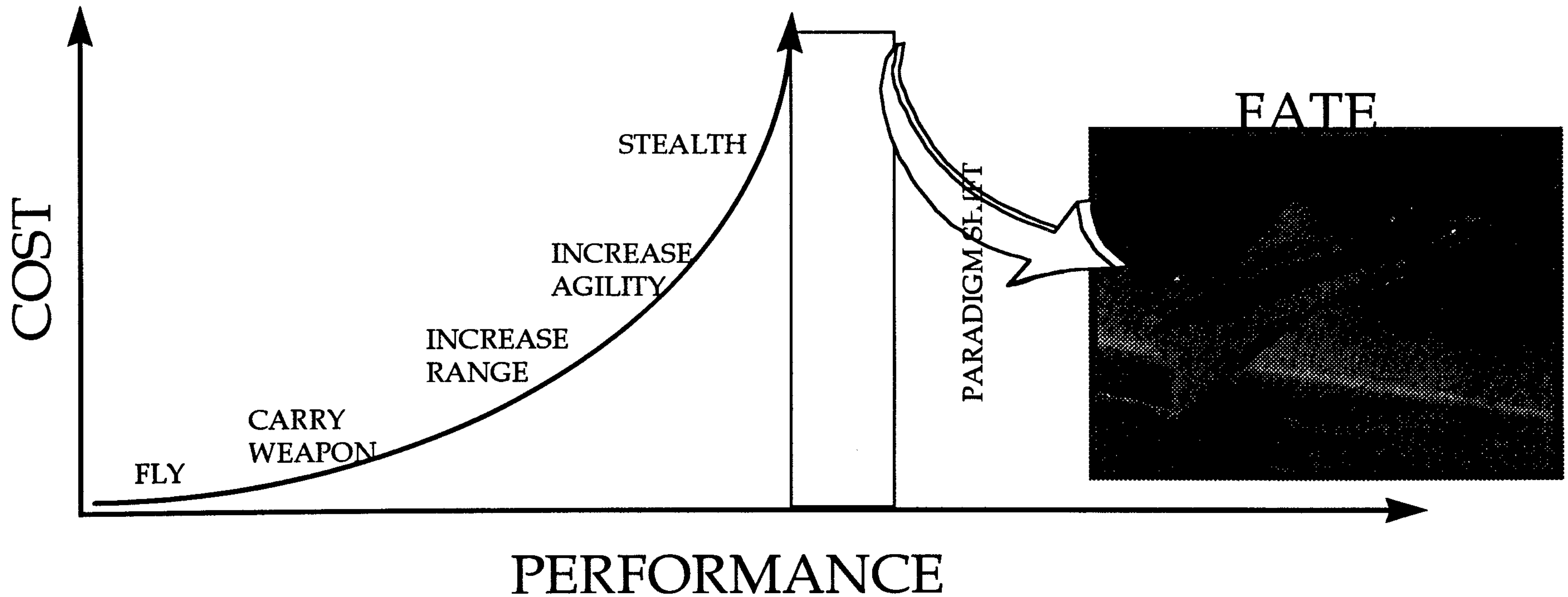
VISION

BREAK THE PARADIGM THAT HIGH PERFORMANCE CAN ONLY BE ACHIEVED AT HIGH COST



ENABLE DRAMATIC COST REDUCTIONS AND PERFORMANCE GAINS THROUGH THE DEVELOPMENT OF MULTIDISCIPLINARY AIRFRAME SYSTEMS

THE FIXED WING VEHICLE TECHNOLOGY DEVELOPMENT APPROACH PROCESS

TDA

- TO DEVELOP A 15 YEAR PLAN LEADING TO A PROGRAM FOR DOD/NASA/ INDUSTRY/ACADEMIA MILITARY FIXED WING VEHICLE S&T INVESTMENT IN FIVE TECHNOLOGY EFFORTS:
  - AERODYNAMICS
  - FLIGHT CONTROL
  - STRUCTURES
  - SUBSYSTEMS
  - INTEGRATION/DEMONSTRATION

9/10/97

SCOPE

TDA

- **THREE FAMILIES OF AIRCRAFT/ POINT OF DEPARTURE, STATE-OF-THE-ART**

FIGHTER/ATTACK	**F-22, F-18E/F**
AIRLIFT/PATROL/ BOMBER	**C-17, P-3, B-2**
SOF	**H/MC-130J**

- **THREE TIMEFRAMES: 2003, 2008, 2013**

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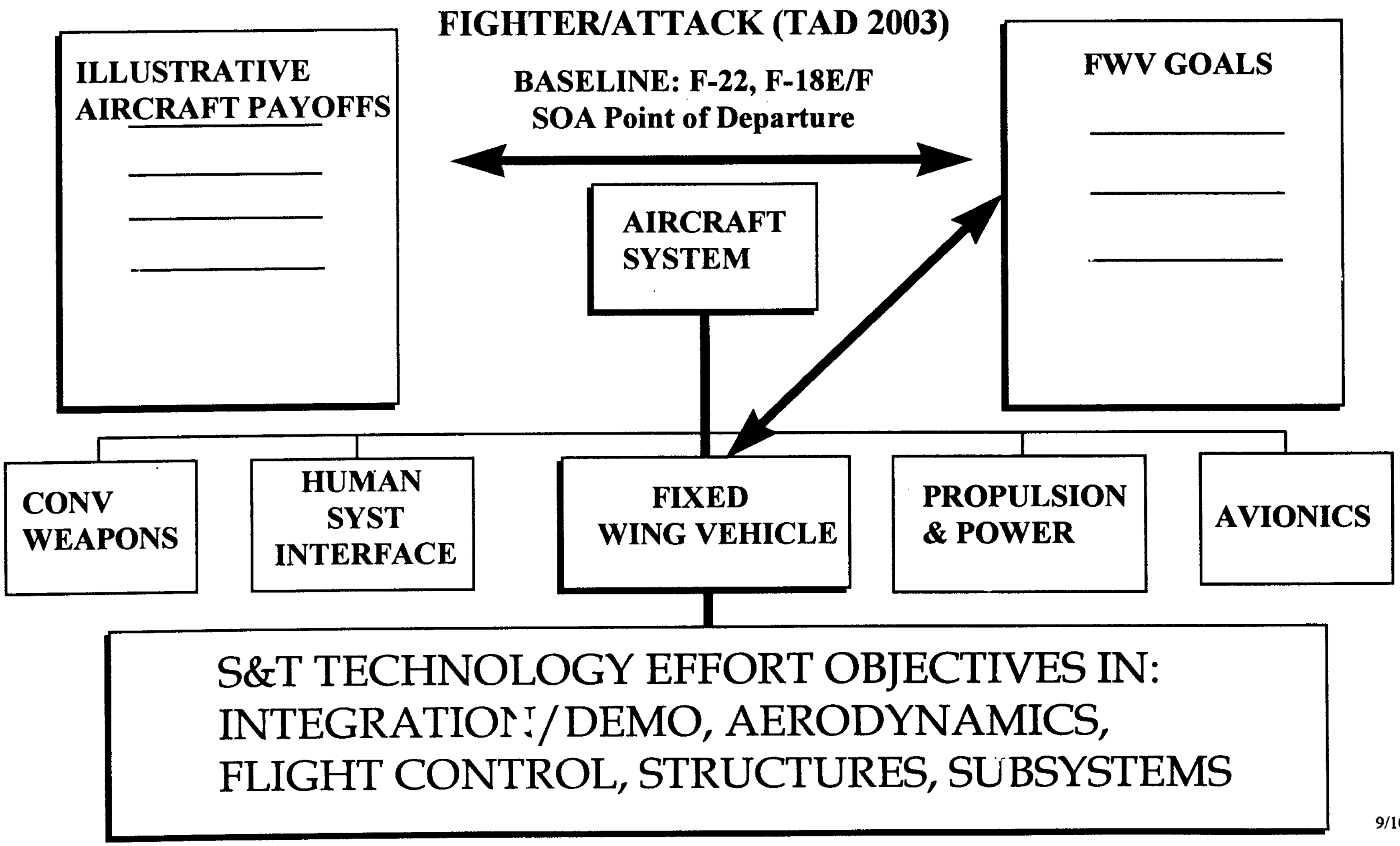
OVERVIEW DIAGRAMS
(one for each Family and Timeframe)

TDA



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FWV-TDA S&T PAYOFFS, GOALS, AND OBJECTIVES
FIGHTER/ATTACK (PHASE I)

AIRCRAFT PAYOFFS

- 10% RED. ACQUISITION COSTS
- 10% RED. OPERATIONS & SUPPORT COSTS
- 5% INCR. LETHALITY
- 25% INCR. MISSION RANGE*
- 15% RED. SUSCEPTIBILITY
- 25% INCR. PAYLOAD*
- 10% INCR. OPERATIONAL READINESS
- 15% RED. VULNERABILITY
- 10% RED. TAKE-OFF GROSS WT.

ASTERISK (*): EITHER/OR

1995 SOA BASELINE POINT OF DEPARTURE: F-22, F-18 E/F

SUBAREA GOALS

SUBAREA GOALS	PILOTED	UNINHABITED
DELTA UNIT PRODUCTION COST AT T-1 *[$ divided by AVW(lb.)]*	0%	XX%
DELTA OPS. & SUPPORT COST PER FLT. HR. *[($/Flt.Hr) divided by AVW(lb.)]*	0%	XX%
DELTA DEVELOPMENT COST (MS I - MS III) *[$ divided by AVW(lb.)]*	0%	XX%
RED. AIR VEHICLE WEIGHT FRACTION *[AVW(lb.) divided by TOGW(lb.)]*	8%	XX%
INCR. LIFT/DRAG *[L/D divided by $(b^2/\text{wetted area})^{1/2}$]*	10%	XX%
INCR. CONTROLLABLE AOA ENVELOPE	20%	20%

NOTE: SIGNATURE, VULNERABILITY, AND RELIABILITY BASELINE OR BETTER.

AIRCRAFT SYSTEM

- CONV WEAPONS
- HUMAN SYST INTERFACE
- **FIXED WING VEHICLE**
- PROPULSION & POWER
- AVIONICS

INTEGRATION TECHNOLOGY

AERO OBJECTIVES
- 10% INCR. CRUISE & MNV. LIFT/DRAG
- 20% INCR. LANDING APPROACH LIFT COEF.
- 25% RED. NOZZLE WT.
- 50% RED. AIR INDUCTION SYSTEM WT.
- 30% RED. AERO DESIGN CYCLE TIME

FLIGHT CONTROL OBJECTIVES
- 15% RED. WT./DRAG TAILS & CTRL SYS
- 25% RED. FCS DEVEL. COSTS
- 20% INCR. AGILITY
- 70% RED. CONTROL RELATED ACCIDENTS
- 20% RED. FCS O&S COST

SUBSYSTEMS OBJECTIVES
- 20% RED. SUBS. PROD. COST @ T-1
- 40% RED. SUBS. O&S COST
- 20% RED. SUBS. EMD COST
- 20% RED. SUBS. WT.

STRUCTURES OBJECTIVES
- 30% RED. STRUCTURAL MFG. COSTS
- 30% RED. STRUCTURAL O&S COSTS
- 25% RED. STRUCTURAL DEVEL. COST
- 20% RED. STRUCTURAL WT.

PERVASIVE MFG TECH OBJECTIVES
- 25% RED. COMPOSITE FAB. COSTS

PERVASIVE MAT'L TECH OBJECTIVES
- TBD

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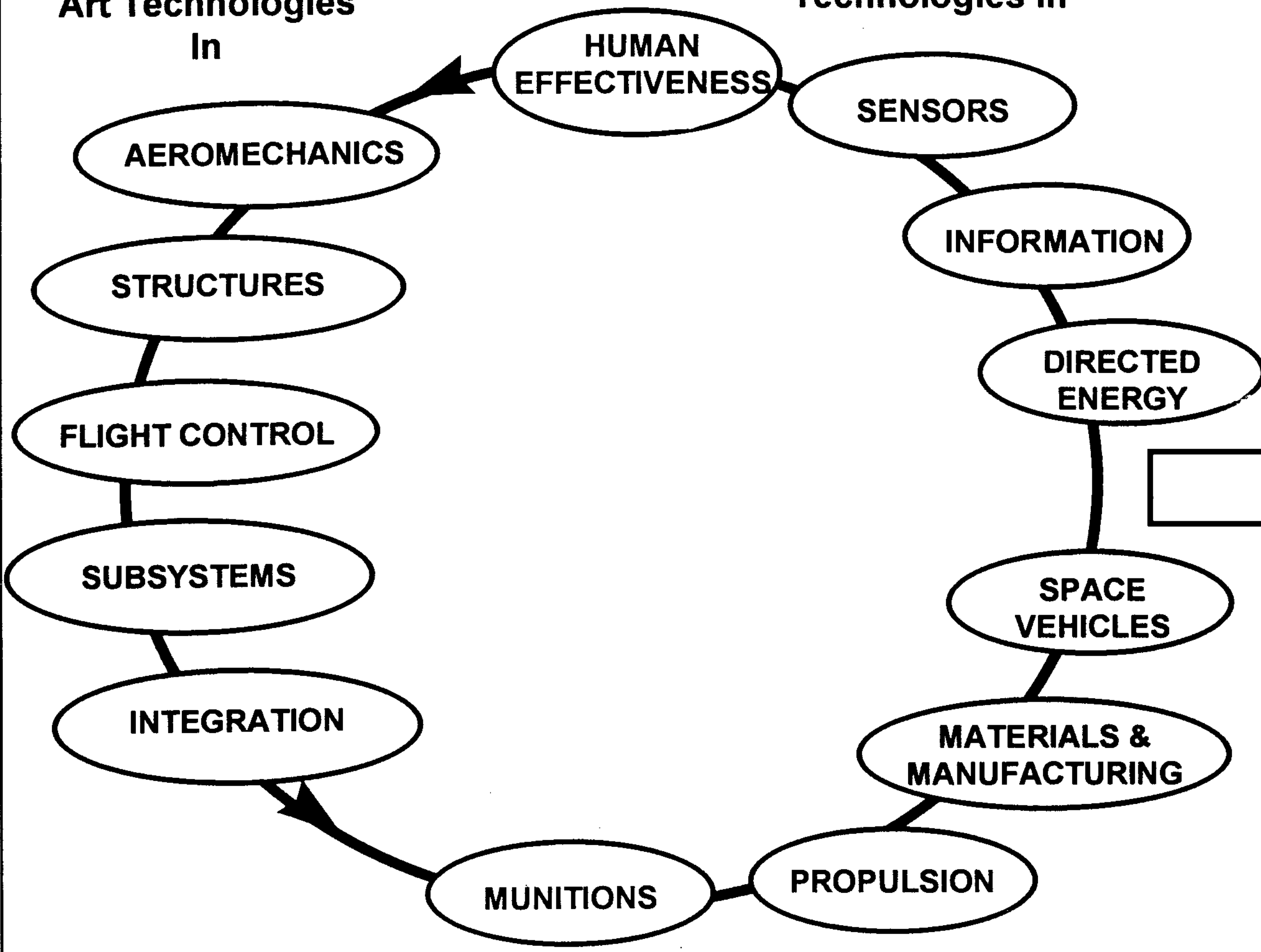
Air Vehicles Technology Development

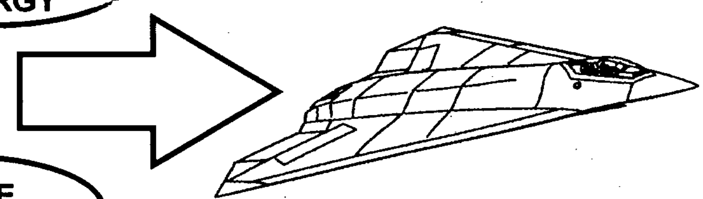
New or State of the Art Technologies In

Integrate With Technologies In



Yielding

Evolutionary / Revolutionary Technology Sets & Design Methods



To Enable New & Improved Aerospace Vehicles

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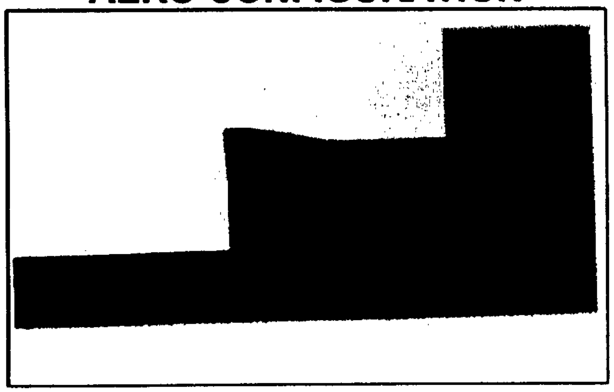
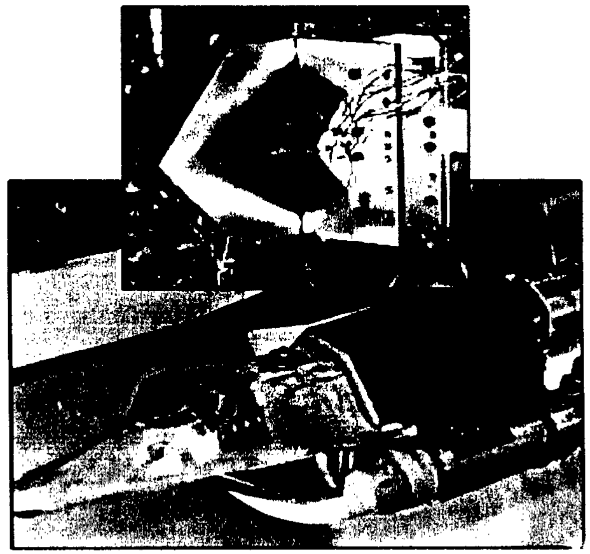
AEROMECHANICS CORE COMPETENCIES

AERO CONFIGURATION



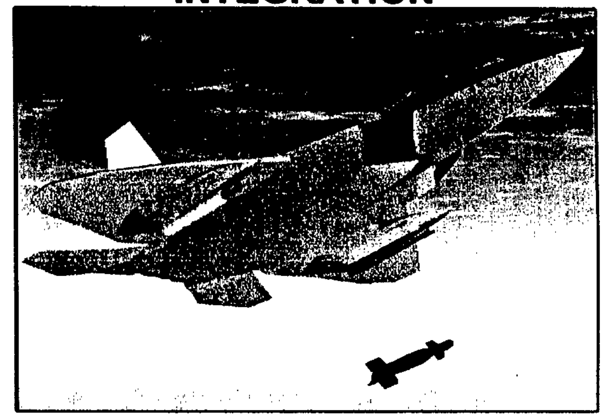
- Aero Configs for Survivable A/C
- High L/D Technologies

AIRFRAME PROPULSION INTEGRATION



- Affordable, Survivable Inlets
- Affordable, Survivable Nozzles

AIRFRAME WEAPONS INTEGRATION

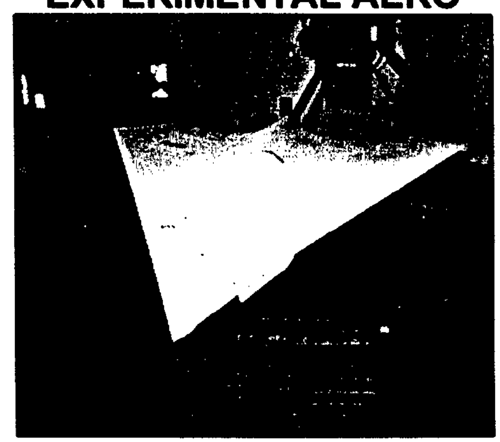


- Weapons Carriage for Survivable A/C
- Active Flow Control of Bays

COMPUTATIONAL FLUID DYNAMICS

- Basic Research for CFD and CEM
- Aero Design Optimization CFD

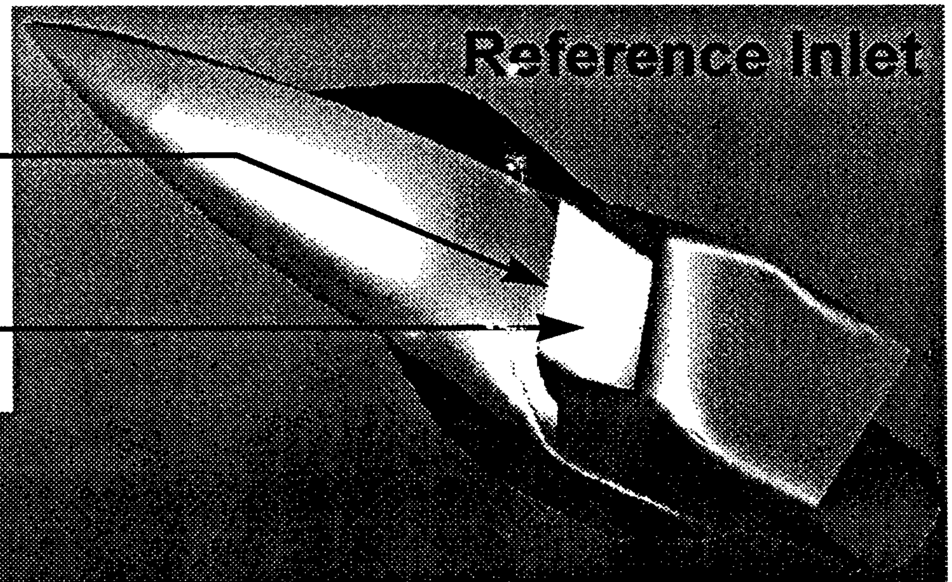
EXPERIMENTAL AERO



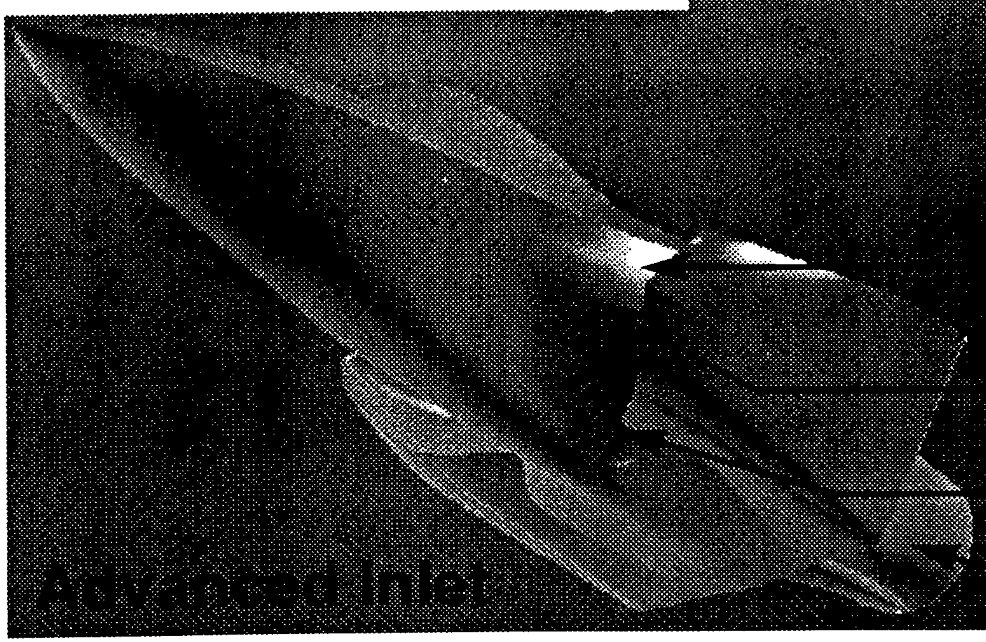
- Subsonic Aerospace Res Lab
- Vertical Wind Tunnel

ADVANCED INLET INTEGRATION

System Features of Reference and Advanced Inlets

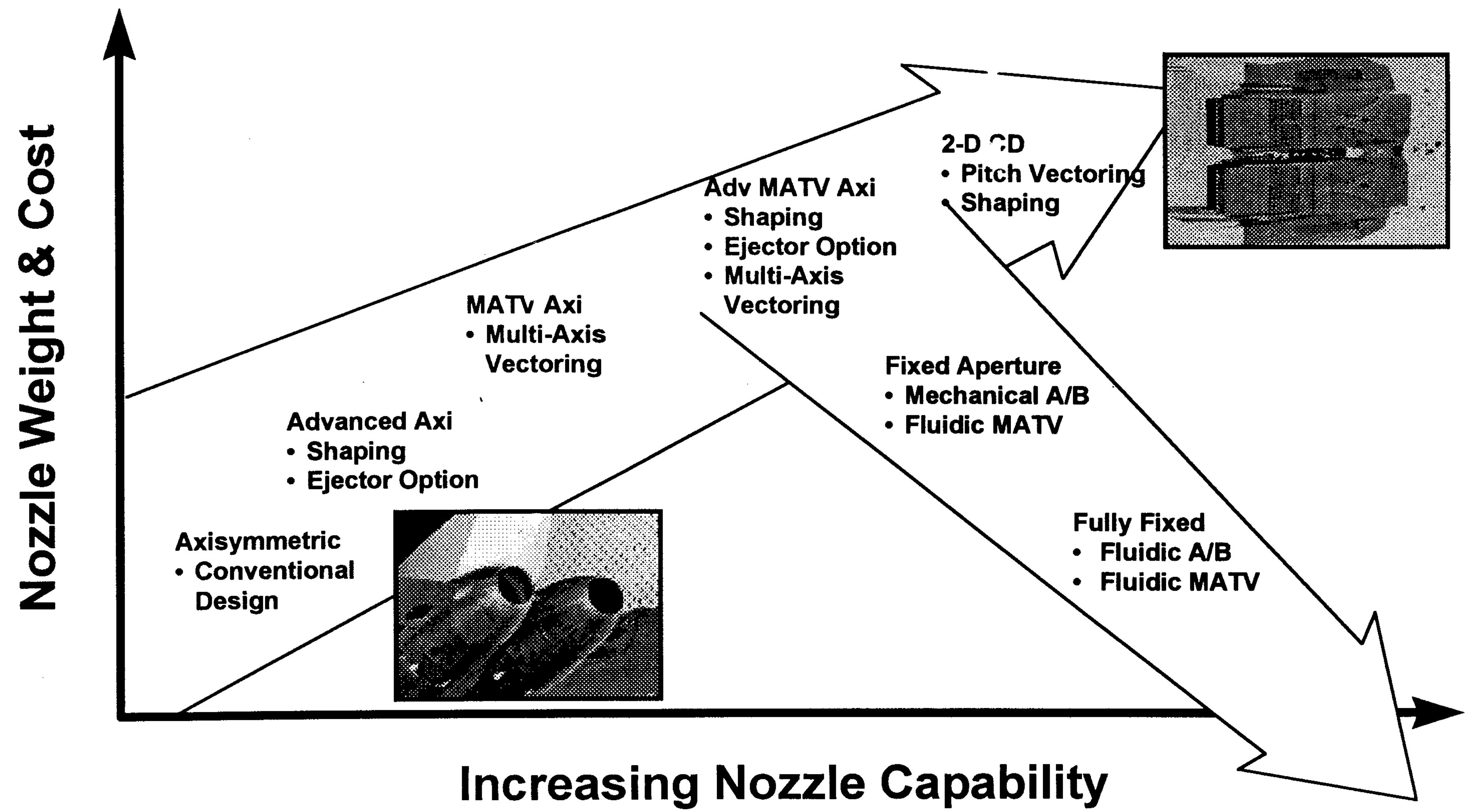


Diverter
F-22 Aperture



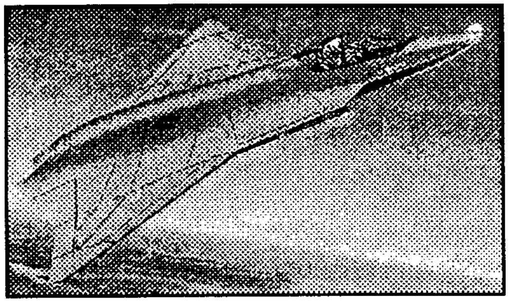
- Diverterless Aperture
- Contoured Compression Surface
- Forward-Swept Cowl
- Compact Diffuser

Why the Fixed Nozzle Approach?



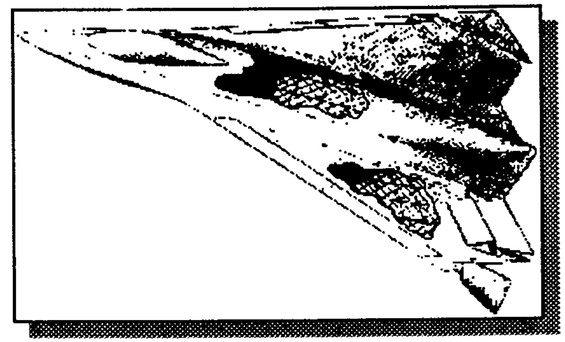
STRUCTURES TECHNOLOGY PROGRAMS

Structural Technology Integration



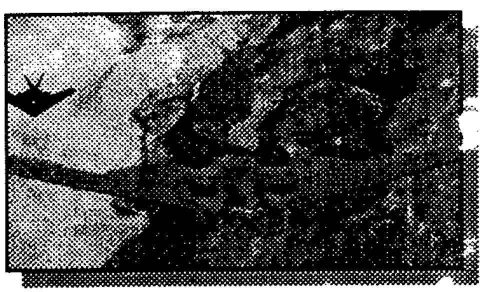
- *Affordable Airframe Structures*
- **Active Aeroelastic Structures**
- **Multifunctional Airframe Structures**
- *Multidisciplinary Design and Analysis Methods*

Smart Structures



- **Adaptive Structures**
- *Vibration Suppression*
- *Smart Skins*

Extreme Environment Structures



- *Structural Temperature Control*
- *Affordable Exhaust-Washed Structures*

Structural Integrity of Aging Aircraft

- *Repairs*
- **Corrosion/Fatigue**
- *Widespread Fatigue Damage*
- **Dynamics & Noise Suppression**

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STRUCTURAL TECHNOLOGY INTEGRATION
Affordable Airframe Structures

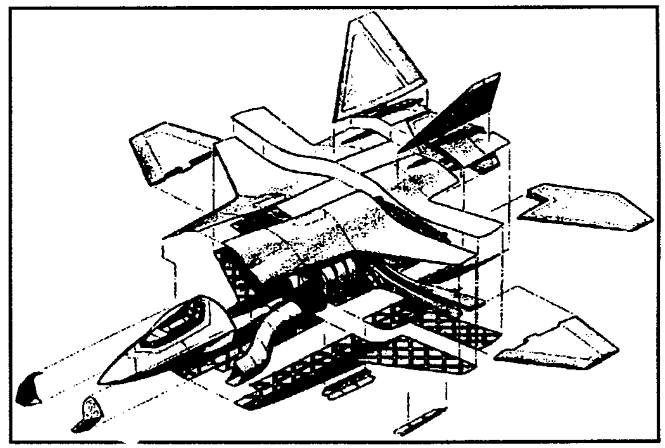
COMPOSITES AFFORDABILITY INITIATIVE

OBJECTIVE

- Demonstrate & Validate Inherent Benefits of Composite Technology
  - Couple innovative designs to manufacturing processes

APPROACH

- Develop & Validate Enabling Technologies
- Establish Design Concepts & Methods
- Establish Industrial-Base Confidence



PAYOFF

- Viable Industrial Base for Affordable Composites

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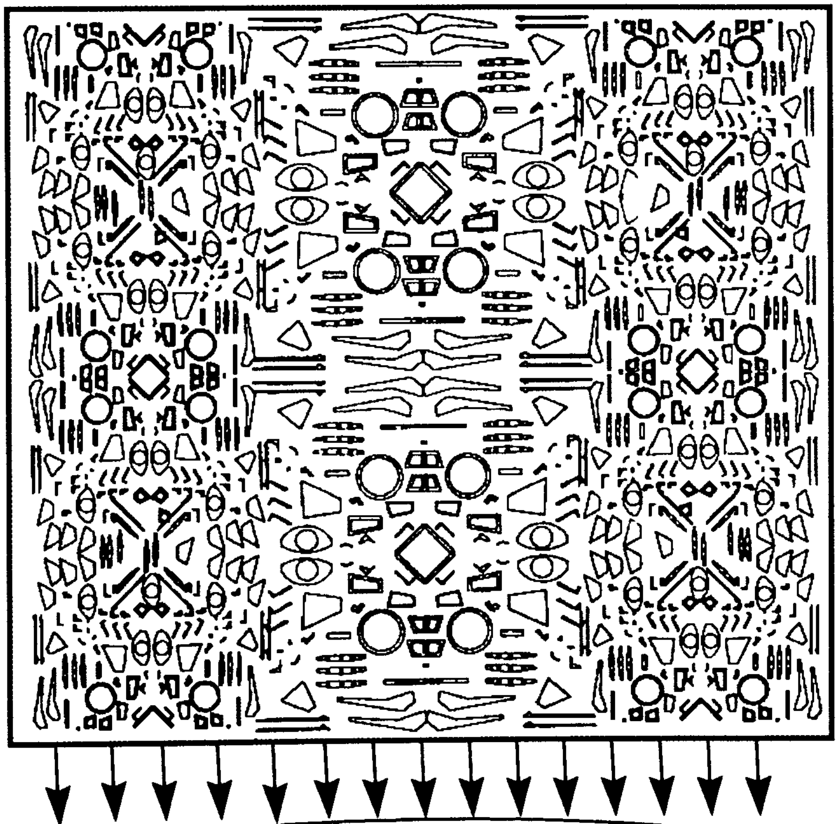
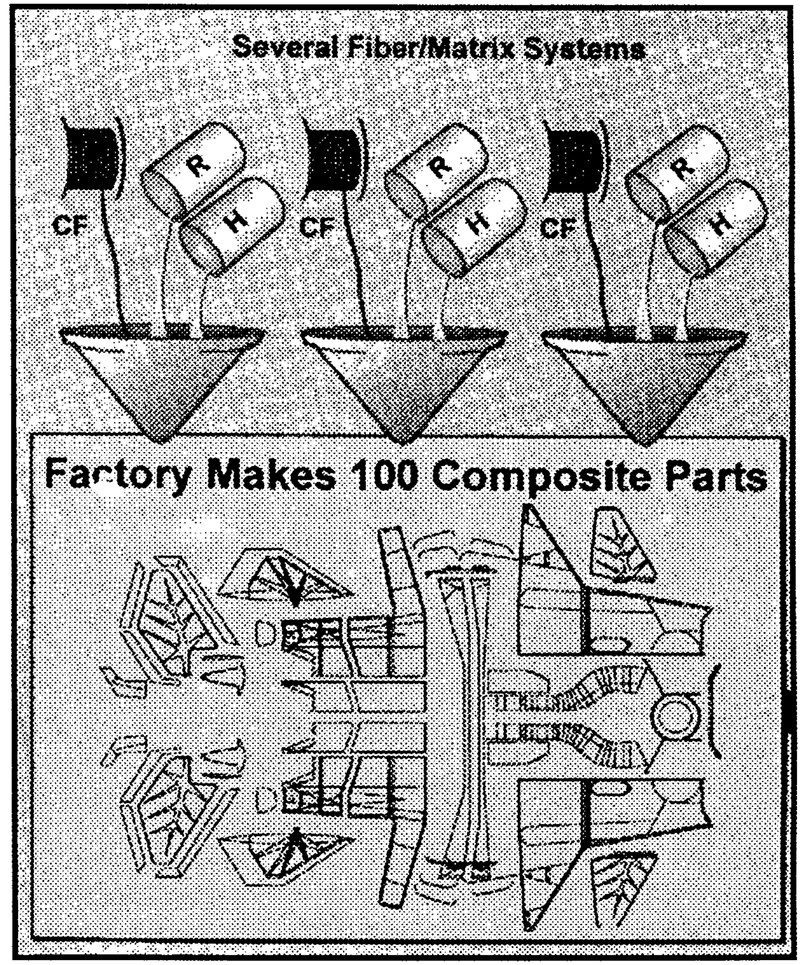
Traditional Airframe



Factory Activity is Primarily Assembly

~11,000 Metal Component-
~600 Composite Components
~135,000 Fasteners
High $ Vendor Markup

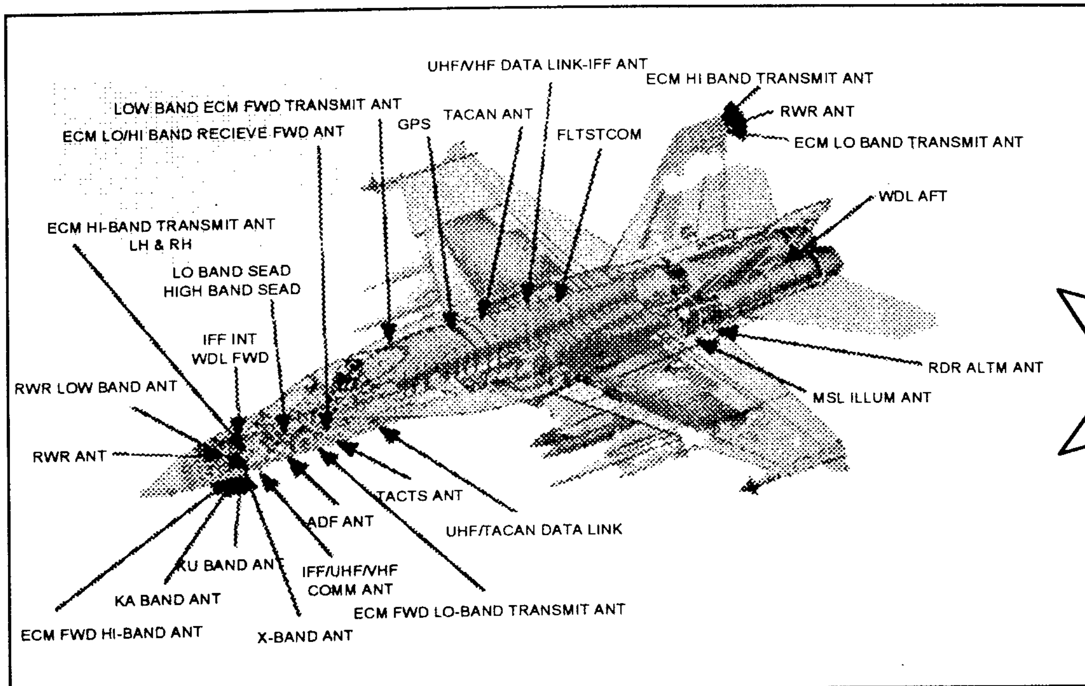
Goal for Unitized Airframe

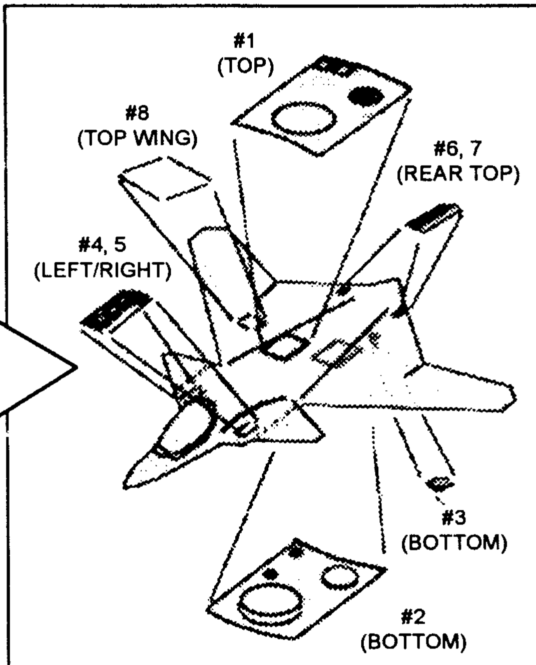


~450 Metal Components
~6000 Fasteners
89% Composite

SMART STRUCTURES
Smart Skins

CONFORMAL LOAD BEARING ANTENNA STRUCTURE





TODAYS PROBLEM

- NUMEROUS SINGLE FUNCTION APERTURES
- PARASITIC INTRUSIVE/EXTRUSIVE
- NOT LOADBEARING
- REDUNDANT & LIMITED RF PERFO! .MANCE
- ANTENNA PERFORMANCE COMPRISED
- STRUCTURAL PERFORMANCE COMPROMISED

CLAS SOLUTION

- FEW MULTIFUNCTION ANTENNAS
- LOADBEARING/CONFORMAL
- APERTUR. SIZED FOR PERFORMANCE
- PERFORMANCE LOCATED APERTURE
- STRUCTURAL EFFICIENCY MAINTAINED

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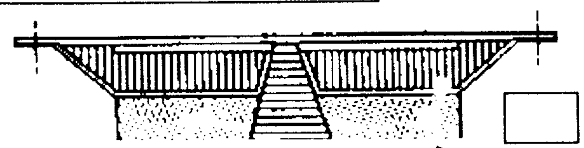
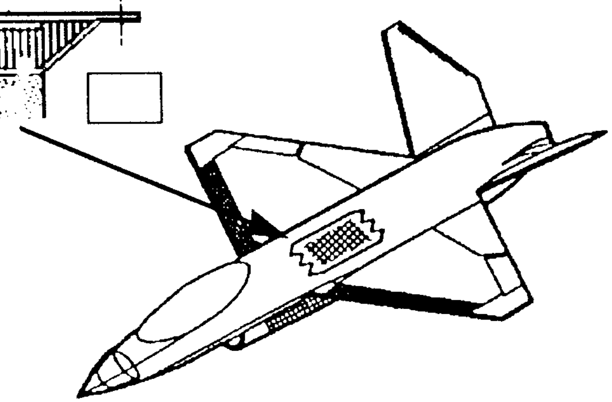
SMART STRUCTURES

Smart Skins

CONFORMAL LOAD BEARING ANTENNA STRUCTURE





OBJECTIVE

Develop & demonstrate embedment of RF apertures in load-bearing a/c structure

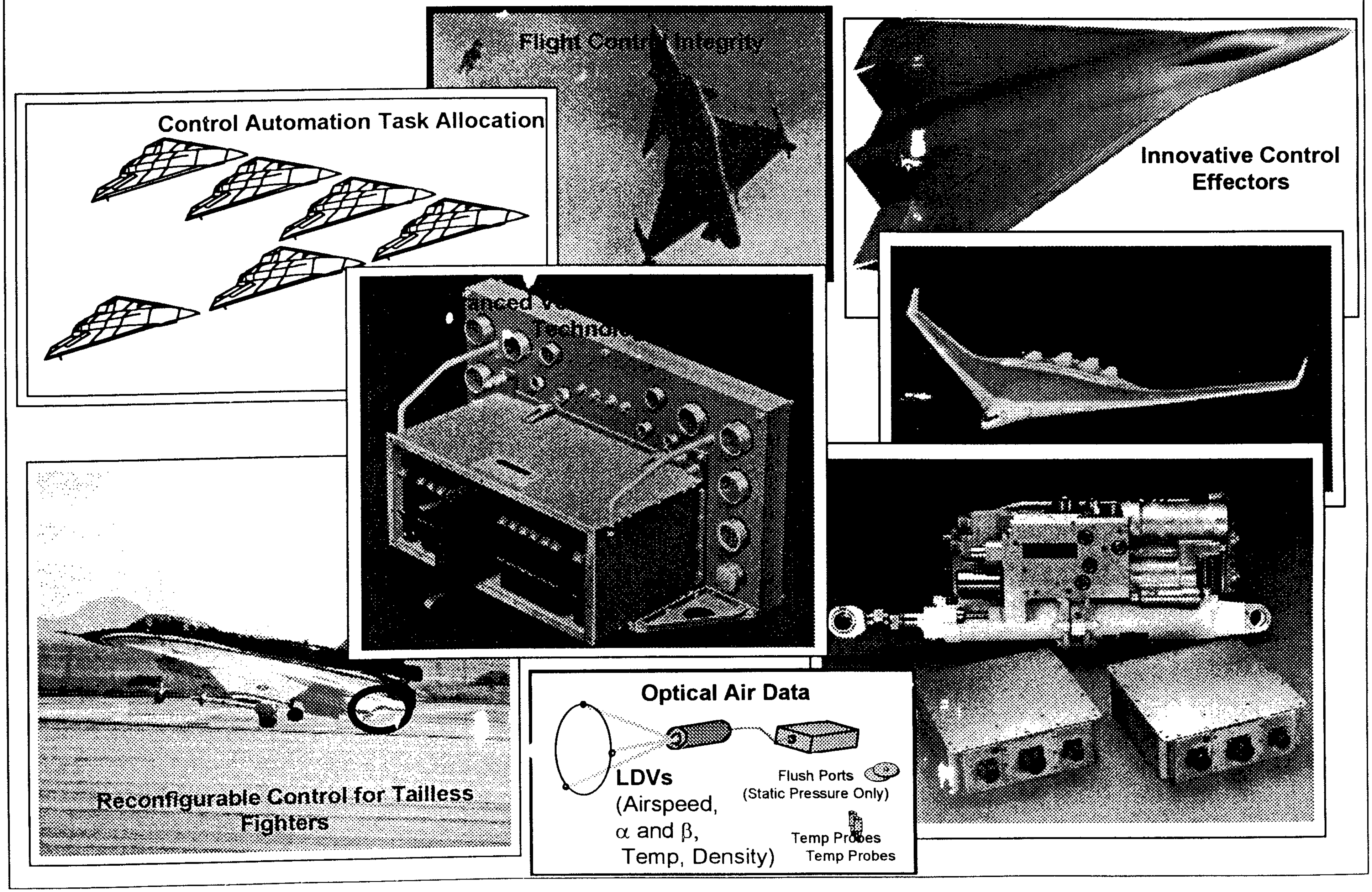
APPROACH

- Design and fabricate upper and lower fuselage structure
  - Incorporate load-bearing wide-band antenna
- Perform ground test of full-scale component structure
  - Limit load tests
  - Electromagnetic performance

IMPACT

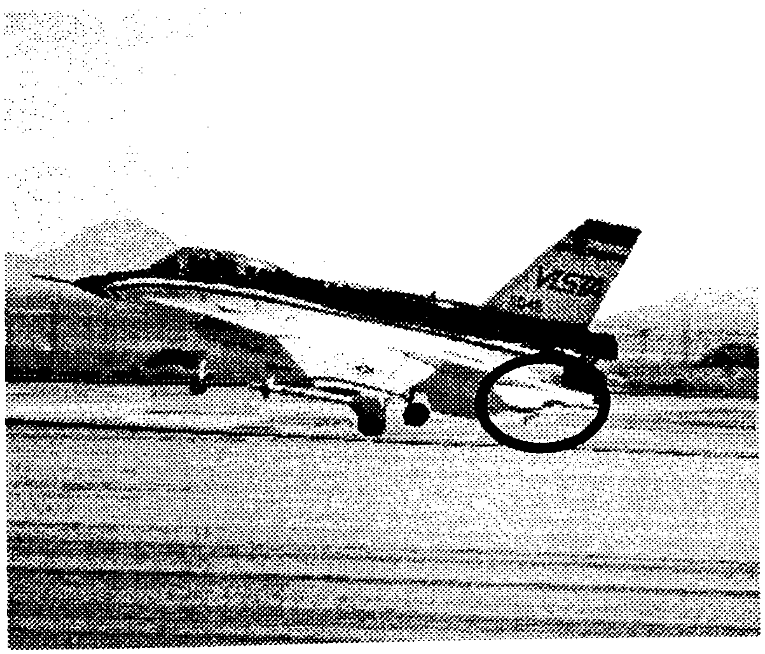
- Improved survivability
- Better antenna performance (range and coverage enhancements)
- Drag reduction / range improvement
- Cost savings (e.g., $250K per airframe on F-22)
- Weight savings (e.g., 70 lbs per airframe on F-22)

MAJOR FLIGHT CONTROL PROGRAMS



Self-Designing Controller

Wright Laboratory, Air Force Office of Scientific Research, Lockheed Martin, Barron and Associates, and Calspan



Objective

Develop and flight test adaptive control laws to optimize performance

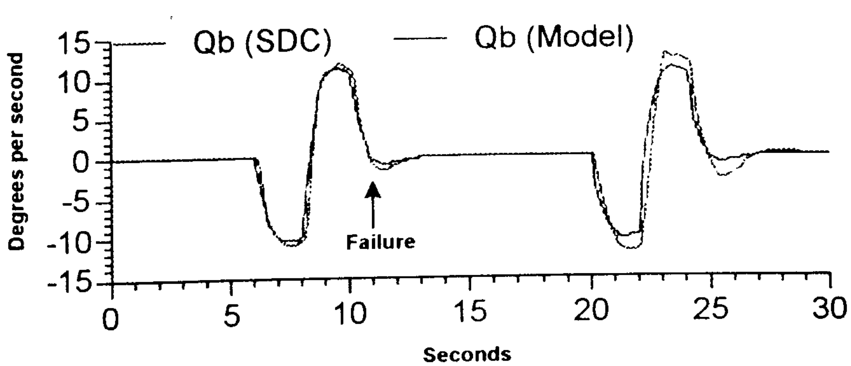
Payoff

- **Damage tolerance**
- **Affordable design methodology**

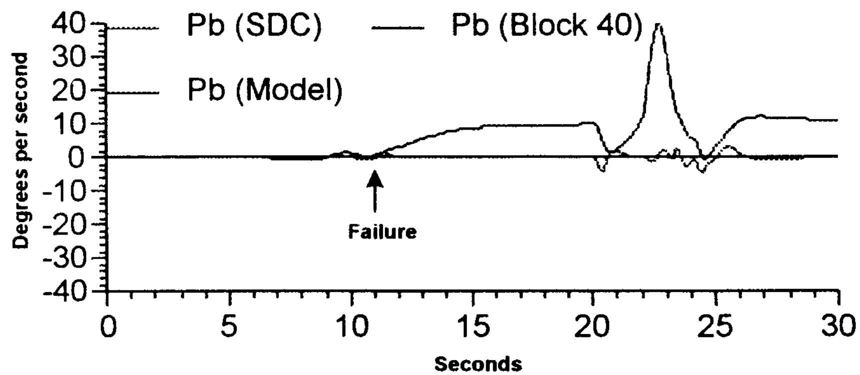
Major Accomplishment: Land with Failures

SELF-DESIGNING CONTROLLER
Simulation Results

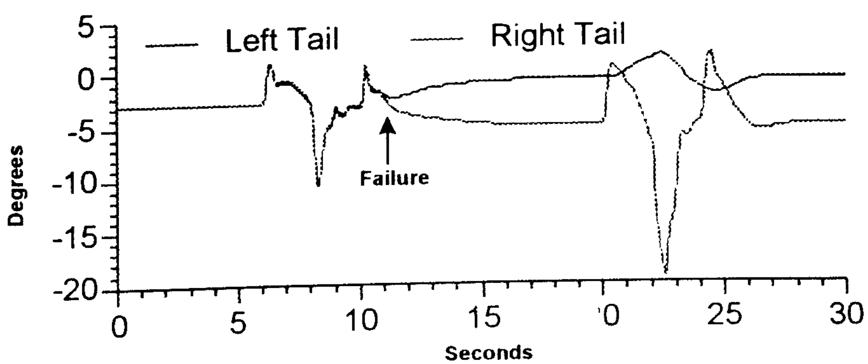
Pitch and Roll Responses to Pitch Doublet Command
0% Effc ctive Left Horizontal Tail at 11 Sec.



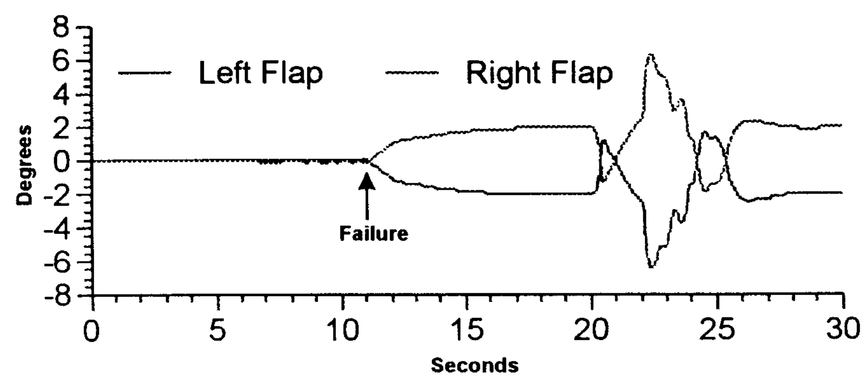
Aircraft Body Axis Pitch Rate



Aircraft Body Axis Roll Rate



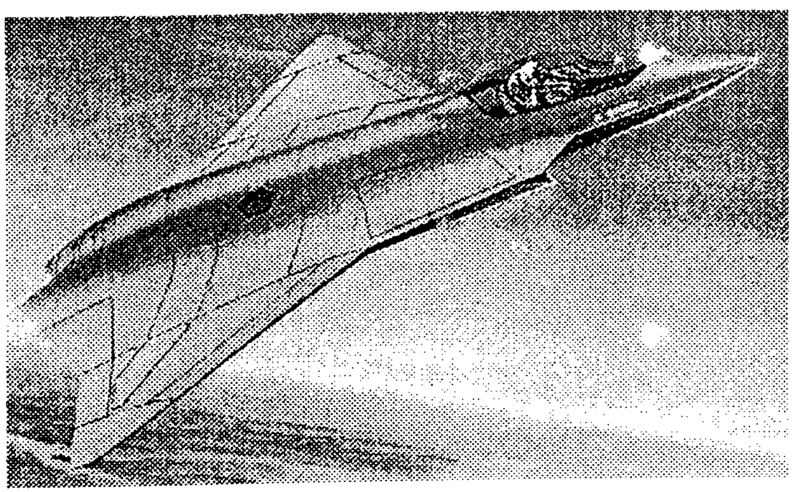
Left and Right Horizontal Tail Position



Left and Right Flap Position

Reconfigurable Control for Tailless A/C (RESTORE)

Wright Laboratory, Lockheed Martin Tactical Aircraft Systems, McDonnell Douglas Aircraft



Objective

On-line control design

- multi-axis instabilities
- coupled effectors

Payoff

- Reduced life cycle cost
- Increased aircraft survivability

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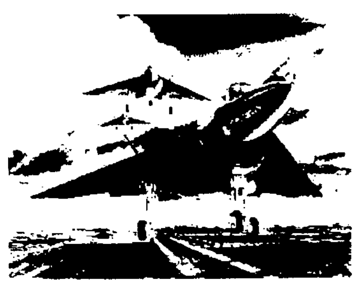
Power-By-Wire Actuation
System Benefits

- Enabling Technology for More Electric Aircraft (MEA)
- Pervasive to New A/C Designs & Retrofit/Upgrade

Maintainability
- Reduced Logistics Tail
- Eliminates CHS Support Equipment
- Improved MTBF
- Improved MTTR (LRU)

Design Payoffs
- Systems Level Weight Savings
- Improved System Survivability
- Reduced Vulnerability
- Increased Subsystem Design Freedom

O&S
- Increased Aircraft Sortie Rate
- Improved Life Cycle Costs
- Improved Mobility/Deployment



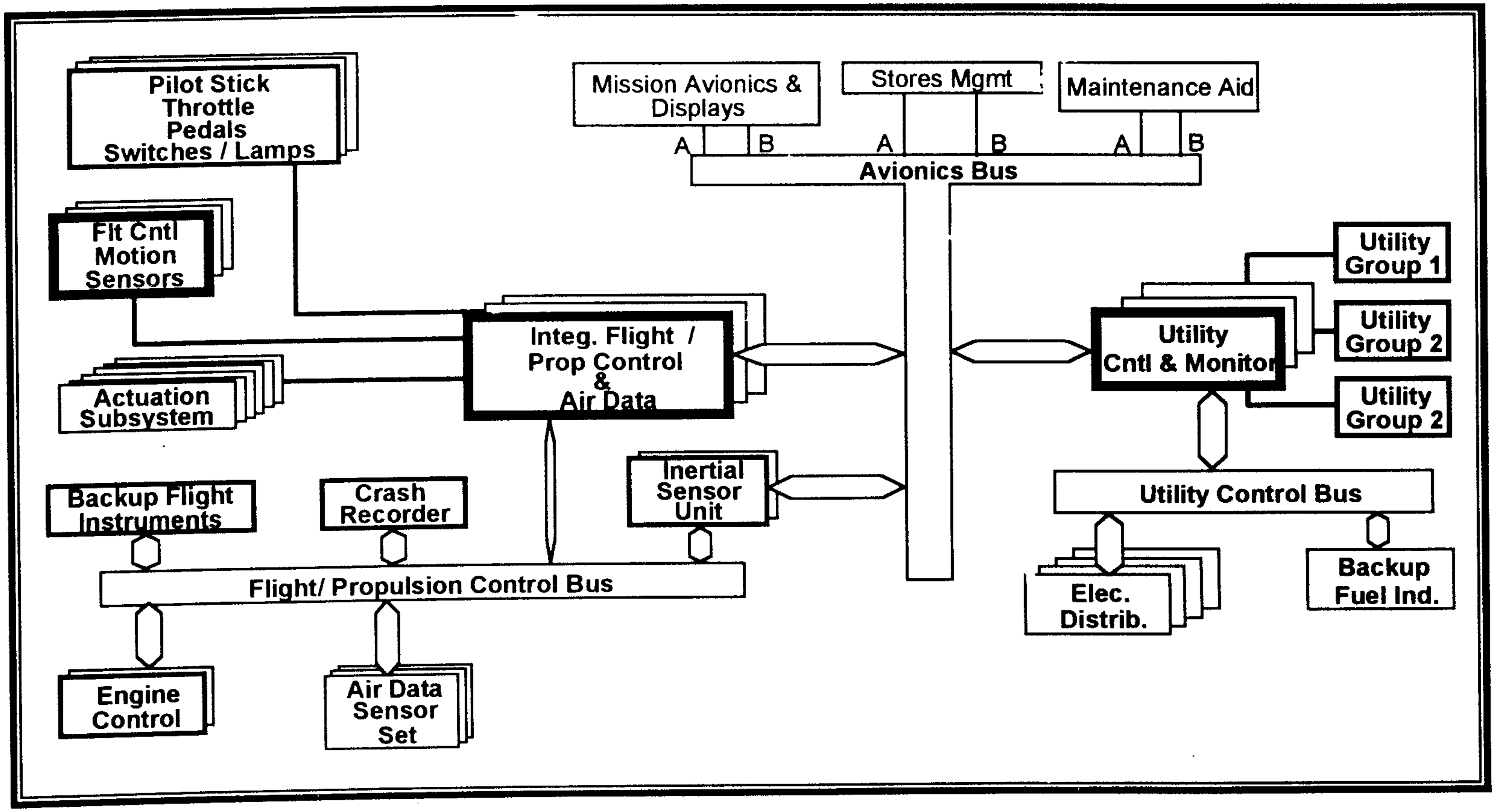
Performance
- Less Secondary Power Extraction
- Improved Thermal Management (Power on Demand)

Power-By-Wire Actuation Flight Validation

Phased Approach

- Joint DoD, Industry IRAD, NASA (Air Force Lead)
- Electrohydrostatic Actuation
- Electromechanical Actuation
- PBW Aileron Flight Validation - 1996-1998
- PBW Stabilator Flight Validation - 2000-2002

Reference Vehicle Management System



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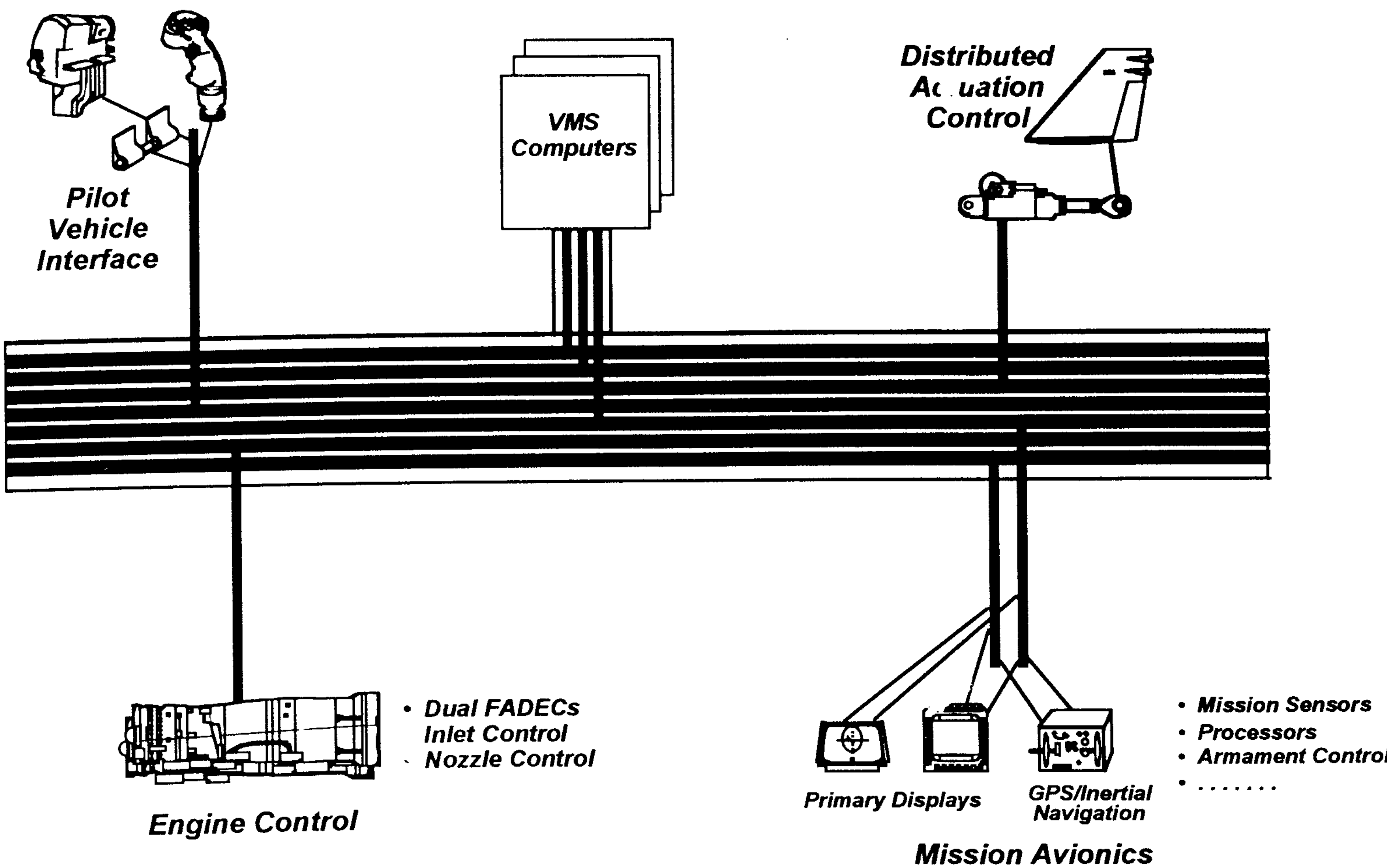
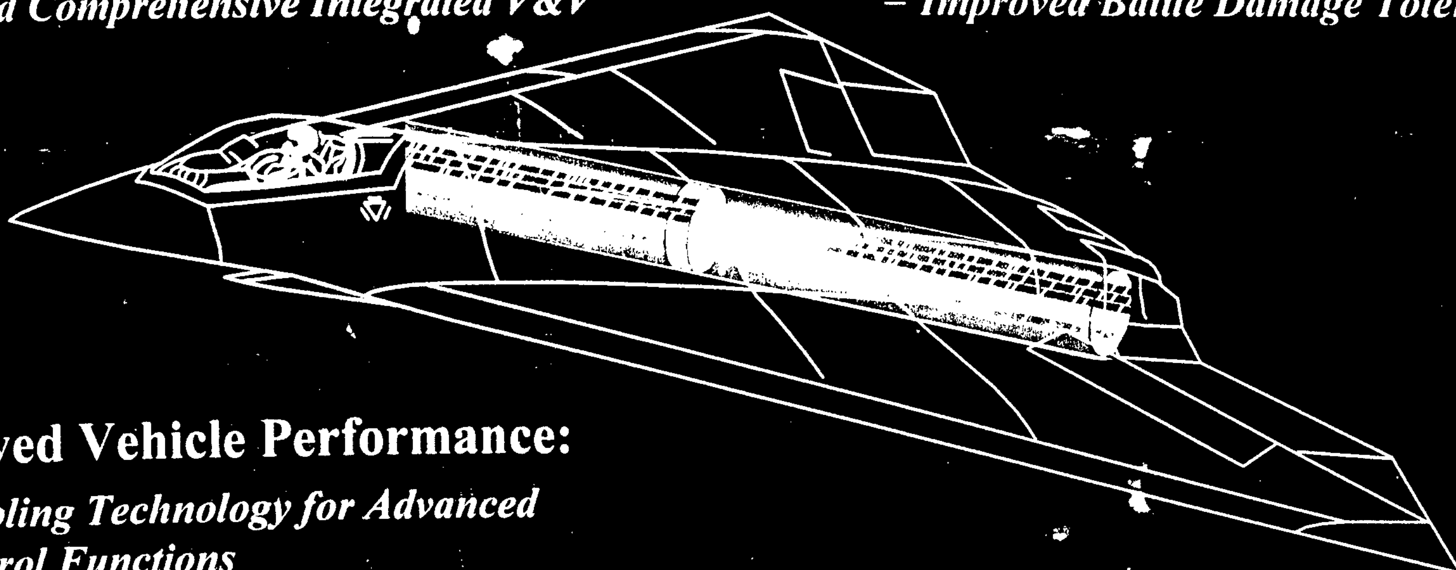
Photonic Vehicle Management System
(TAD 2010)
Wavelength Division Multiplexing on Single Fiber



Photonic VMS Architecture Benefits

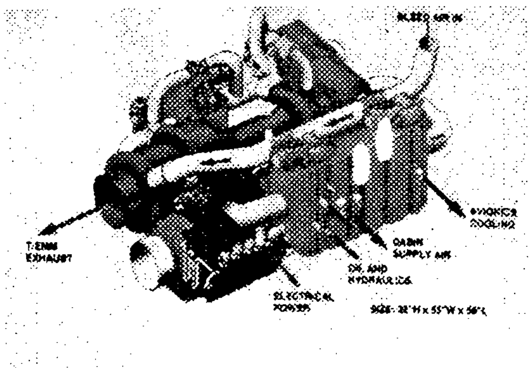
- **Improved Life Cycle Cost:**
  - *Use of Commercial Technologies and Practices*
  - *Reduced Hardware Count*
  - *Improved Design Tools and Techniques*
  - *Rapid Comprehensive Integrated V&V*
- **Improved Vehicle Survivability:**
  - *Improved EMI Tolerance*
  - *Increased Fault Tolerance*
  - *Improved Reliability*
  - *Improved Battle Damage Tolerance*



- **Improved Vehicle Performance:**
  - *Enabling Technology for Advanced Control Functions*
  - *Scaleable Open Architecture for Growth Potential*
  - *Modular Upgrades to Avoid Obsolescence*
- **Reduced Size & Weight:**
  - *Reduced Cabling Weight*
  - *Reduced Parts Count*

Subsystems Core Competencies

Thermal Energy Management



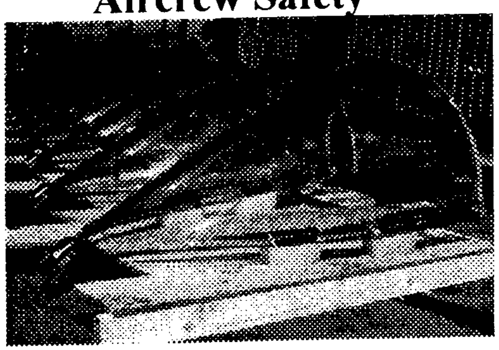
•Components
•Design Assessment

Air Base Technology

•Fire Fighting Technology
•Energy Technology
•Pavement & Facilities

Critical Components

Aircrew Safety

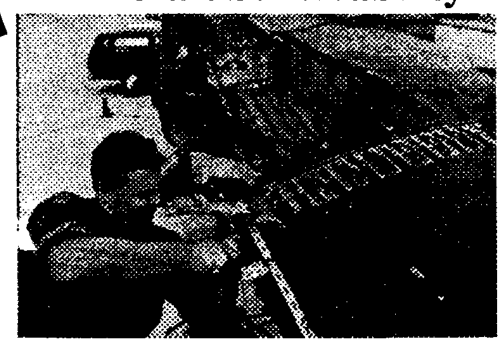


•Transparencies
•Precision Aerial Delivery

Ground Operations

•Landing Gear Systems

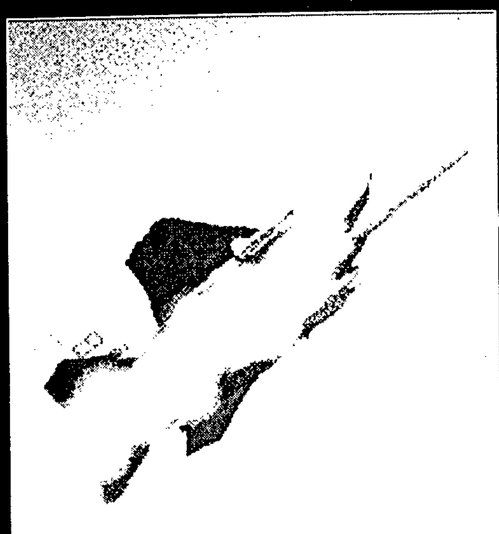
Aircraft Survivability



•Fire Suppression
•Aircraft Battle Damage Repair
•Combat Damage Reduction

DOD Fire Protection Technology

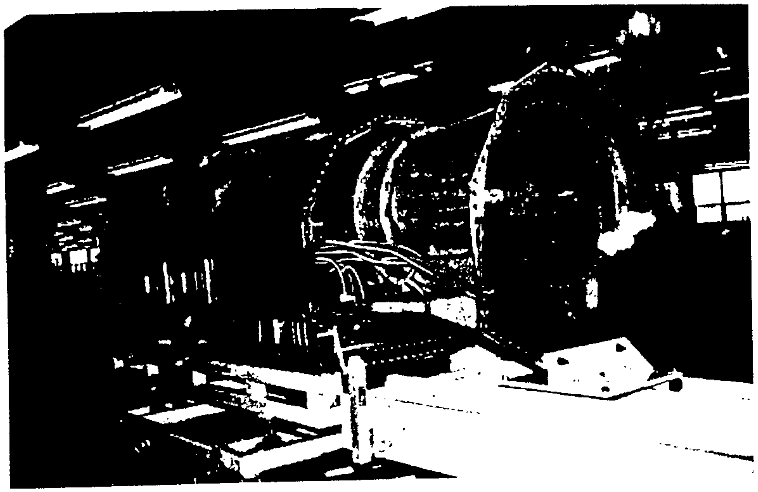
- Goal: Find environmentally friendly alternative to banned Halon 1301 fire suppression chemicals
- Benefits to AF and others:
  - Validated and quantified replacement to Halon 1301 for military aircraft
  - Elimination DOD dependence on Halon 1301 for fire protection
  - Solution transferable to FAA, and others (i.e. Automotive)
  - Follow up work to be fielded by F-22, C-17 and F-16
  - Compliance with current and future EPA standards



Halon Protects Aircraft from fire

Halon is also used in other applications

WL/FIVS FIRE PROTECTION



Engine Nacelle Fire Test Fixture

Dry Bay Fire Test Fixture

- CUSTOMERS
  - ACC: F-22, F-16, JSF
  - AMC: C-17, C-130
- PARTNERS
  - JTCG/AS
  - NAVY
  - FAA
  - NIST (Next Generation Program)
  - INDUSTRY: Boeing, Walter Kidde, BAH
- PRODUCTS
  - HFC-125 Design Equations
    - -- Engine Nacelles and Dry Bays
  - **Gas Generator Design Guidance for Engine Nacelles**
  - Fire Protection Life Cycle Cost Model
  - Engine Nacelle Fire Model
  - Fuel Tank Inerting Technologies

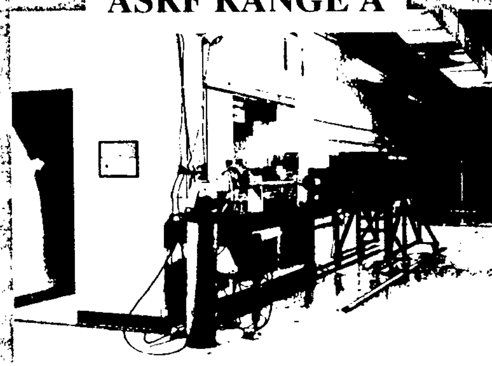

Advanced Combat Maintenance Technology
Advanced Development Program
Developing proven assessment and repair concepts for rapidly returning battle damaged aircraft to an operational status
Assessment
Repair
Methodology
Database
Advanced Technology Products:
•Repair of Advanced Structures
•Computerized Wiring Maintenance Aid
•Transparency Repair System

AIRCRAFT SURVIVABILITY RESEARCH FACILITY

ASRF RANGE 1

THREAT CHARACTERIZATION & MATERIAL EVALUATION

ASRF RANGE A



IMPACT PHYSICS RESEARCH

ASRF RANGE 2

RAM, FIRE, & EXPLOSION SUPPRESSION

ASRF RANGE 4

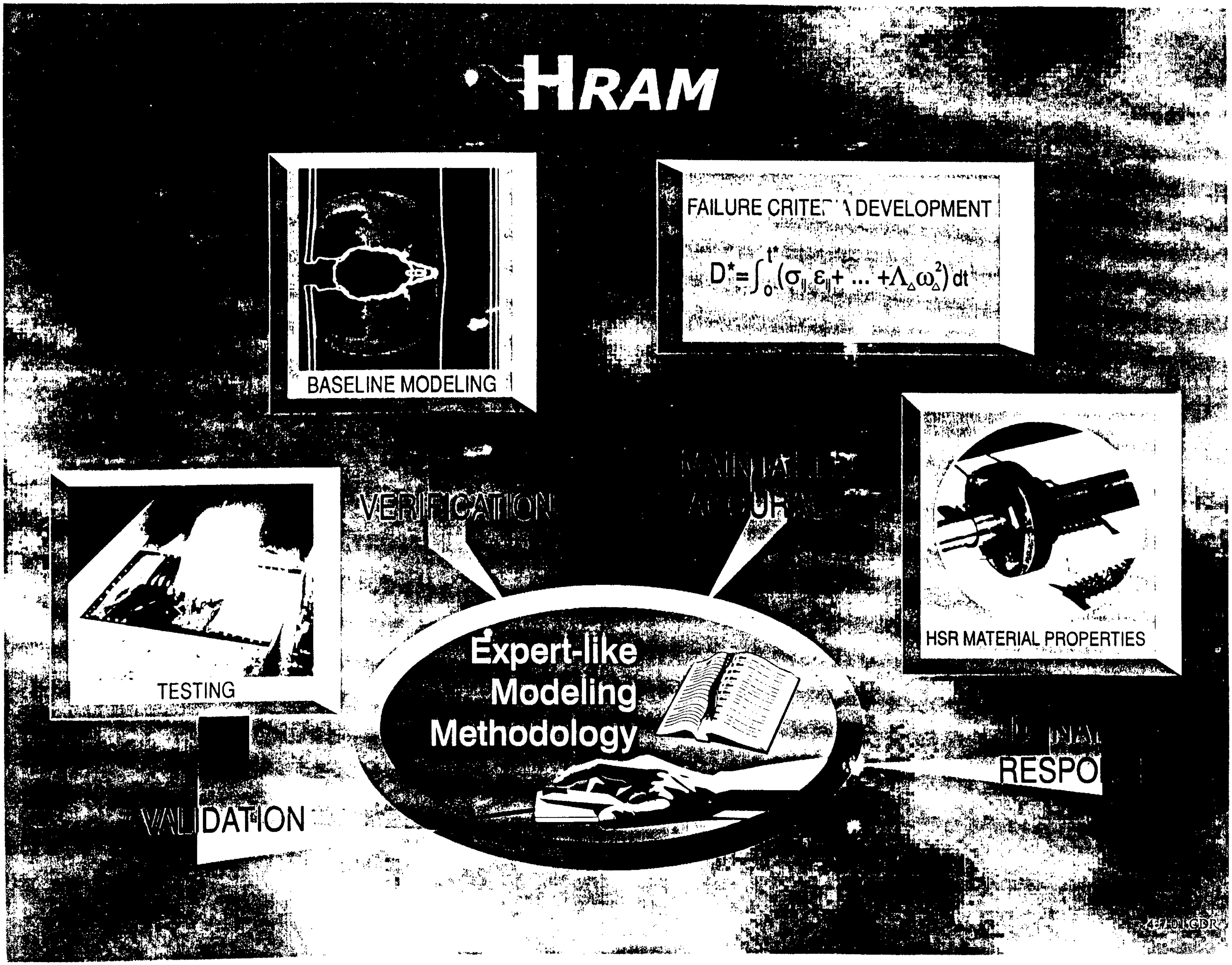
HYPERVELOCITY IMPACT STUDIES

A/C ENGINE NACELLE FIRE TEST SIMULATOR

FIRE DETECTION/EXTINGUISHING METHODS

ASRF RANGE 3

FULL-SCALE S/V TESTING



HRAM
BASELINE MODELING
FAILURE CRITE DEVELOPMENT
$D^* = \int_0^{t^*} (\sigma_{ij}\varepsilon_{ij} + \ldots + \Lambda_\Delta \omega_\Delta^2)\, dt$
VERIFICATION
TESTING
HSR MATERIAL PROPERTIES
Expert-like
Modeling
Methodology
VALIDATION

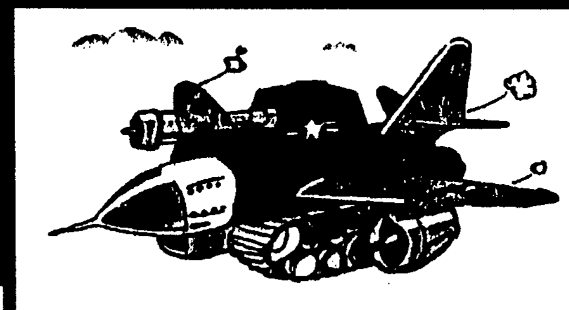
METHODOLOGY IMPROVEMENTS

CODES

CURRENT

- Little V&V
- Poor understanding of phenomena
- Poor database
- Worst-case or nonexisting requirements

Over/Under Design



THE FUTURE

- Validated
- Physics based
- Good database
- Realistic requirements

Optimal Design